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ONE "LUMP" OR TWO?: ARE THERE INDEPENDENT OR COMMON ORTHOGRAPHIC LEXICONS FOR READING AND SPELLING?

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE DOCTOR OF PHILOSOPHY

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ABSTRACT

One "Lump" or Two? Are there Independent or Common Orthographic Lexicons for Reading and Spelling?

by

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Three theories on the relationship between the lexical orthographic representations utilized in reading and spelling can be distinguished. They are a common or single lexicon theory, an independent lexicons theory, and a "separate but linked" lexicons theory. Little research with normal populations has addressed these issues. Neuropsychological studies have produced mixed results. Three experiments examined the validity of each of these theories utilizing both long-term and short-term priming paradigms. Experiment 1 examined the relationship between reading and spelling utilizing a perceptual identification task, and found facilitation in terms of accuracy of later perceptual identification performance only for previously read items. Experiment 2a found marginally significant facilitation of later spelling performance from previously spelling an item at study in a spelling-probe task but no significant facilitation in a missing-letter task. Experiment 2b found significant facilitation from previously spelling a word at study to later performance on a spelling-probe task. However, this facilitation was only significant across subjects and not items. Experiment 3 examined the influence of spelling on reading and reading on spelling utilizing a short-term priming paradigm. Subjects performed
either a spelling-probe or a lexical decision task, and facilitation was measured to repeated items that appeared with one, two, five, and ten items intervening between the first and the second presentations. Significant facilitation was observed from reading to reading, and spelling to spelling, as well as from spelling to reading. No significant priming was obtained from reading to spelling. Read primes produced significantly more priming than spelled primes for read targets. There was no corresponding, statistically significant, advantage for spelled primes over read primes for spelled targets. No significant interactions with the number of intervening items (lag) on the amount of priming were observed. These data are interpreted as supportive of a lexical orthographic system which involves two distinct lexicons, (one for input and one for output) which are linked together in some manner.
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Introduction

Reading and spelling are, inarguably, complex tasks requiring the functioning and coordination of many processes. Some of these component processes may be shared between the two tasks and some may be required for only one task. The first part of the discussion below will describe the various components involved in reading and spelling in normal adults according to the most common functional models of these tasks. This discussion is based upon descriptions of the reading and spelling components discussed in Ellis and Young (1988) and Shallice (1988). Figure 1 shows a schematic version of the functional components of the language system excerpted from Ellis & Young (1988).

Components of the Reading System

Current models of reading propose at least two, and possibly three, routes by which normal subjects produce a spoken output for a visual word. The visual input components will be discussed in the greatest detail, in that they are the most relevant to the comparison of reading and spelling processes.

Similar to the processes involved in the perception of any visually presented object, visually presented words must first be analyzed into their component parts. This visual analysis system serves to identify letters in letter strings (both for real written words and for written nonwords, pronounceable or not), encode the position of each of the component letters, and to group letters which belong to part of the same word.
Figure 1:
Components of the Reading and Spelling Systems

Speech

Auditory Analysis

Phonological Input Lexicon

Semantic System

Orthographic Input Lexicon

Phonological Output Lexicon

Semantic System

Orthographic Output Lexicon

Grapheme Level

Writing

Word

Visual Analysis

Phoneme Level

Speech
This letter identification process occurs in parallel across all of the letters in the word. These letters are then identified as abstract graphemic representations such that surface features such as case do not matter. Thus, both "a" and "A" when analyzed are matched to the grapheme /a/. It is the abstract graphemes which are utilized to access representations at the next level.

At the next step in reading the process divides into two routes. The first is a lexical or addressed route to phonology. This route involves the mapping of the abstract graphemic representations onto orthographic lexical representations of whole words which are familiar to the individual. The second route, a sublexical route, involves the mapping of graphemes onto phonemes utilizing some sort of correspondence rules in order to derive the correct pronunciation for the particular letters or letter combinations. It is, however, the addressed or lexical route which is of interest to the current discussion. These lexical representations have been hypothesized to be grouped according to frequency of occurrence, neighborhood (words which are graphemically similar), word class, and possibly by co-occurrence frequency. As stated previously, the representations at this level are abstract, whole-word representations. From here, these representations may be mapped either directly onto abstract lexical representations in a speech output lexicon (bypassing meaning), or they can be mapped onto representations in a central semantic system.

The representations of words in the semantic system has been argued to be based upon constellations of features. Within such a system items that share features, such as category coordinates, would be linked to each other
due to shared features. These features can be physical characteristics, functional characteristics, or others. It is important to note that as currently described the representations in the semantic system are central. That is, the representations in this component are the same representations which are utilized to attach meaning to any type of stimulus. So when the cognitive system attempts to find meaning in an auditory word, a picture, or a visual word, the same semantic representation is accessed for those items. The semantic system is the only component of the cognitive system which is widely agreed upon to be common between all cognitive processes, including reading and spelling.

The remaining components in the reading system are the output components. After a semantic representation has been accessed the entire process repeats in reverse-through the speech output components. The semantic representation accesses a lexical whole-word representation in the speech output lexicon. This representation is utilized to access the constituent phonemes for the word to be produced. Finally, articulatory programs corresponding to the various phonemes are accessed and produced in order to pronounce the word.

Components of the Spelling System

Besides a semantically mediated route from auditory input to graphemic output, there are two other ways in which an individual can derive a written output for an auditory word (see Figure 1). The first is a sublexical route which maps the output of an auditory analysis onto a graphemic output. This involves the matching of individual phonemic representations onto output graphemic representations. This process occurs without reference to any lexical representations, either phonological
or orthographic. In addition, there is a route between input lexical phonological representations and output lexical orthographic representations. These connections bypass the semantic system but involve the matching of whole-word abstract lexical representations in phonology and orthography. The discussion below will address the components involved in the production of a written output from meaning.

The first component involved is the central semantic system. Within this system, representations of features related to particular concepts are activated. As mentioned earlier, these representations are involved in all other cognitive processes as well. These semantic representations are utilized to activate lexical orthographic output representations. These are abstract whole-word representations of all of the spellings of all of the words familiar to the individual. It is these representations which are utilized to access representations of individual graphemes. As mentioned previously, graphemes are abstract representations of all of the individual letters in the language. At this level the representations are still abstract. Selection of output modality (e.g., print vs. cursive) and the type of letter form (upper vs. lower-case) is completed after this level. The remaining components deal with these issues as well as the actual motor output. The allograph level represents the various graphemes in one of two forms or allographs, either upper-case or lower-case. Finally, the motor pattern level represents the various movements which are necessary to produce the different allographic representations.

**Neuropsychological Evidence on Single vs. Dual Lexicons**

Patients who have suffered from brain-damage are often most informative as to the hypothesized structure of cognitive models. It is
assumed that if two components are independent of each other, then it should be possible to damage one and not the other. It should be possible to demonstrate a double dissociation, that is, find a set of patients for whom one component and not the other is damaged and vice versa. Damage to shared or common components should produce similar patterns of performance (i.e., overall accuracy and types of errors) across all tasks which utilize that component. Damage to independent components should affect the performance of only those tasks which utilize each and not others. Therefore, damage to any of the independent components in the reading system should produce only a reading impairment and the same for the independent components involved in the spelling system. As stated previously, at this time the only component which is agreed upon as being shared by the two tasks is the semantic system. How the lexical orthographic representations for input and output are related is still unclear. A single orthographic representation would be more parsimonious; however, the data may indicate that two representations are needed.

Although double dissociations have been reported many times between language production and language comprehension as well as between reading and spelling, it is possible that these impairments occur due to a disruption of more peripheral processes. For example, an individual with an impairment in his or her ability to comprehend spoken language but not to produce it may have a perceptual impairment which disrupts his or her ability to map auditory codes onto phonological representation but not have a problem mapping phonological representations onto articulatory codes. Similarly, an individual may have
an impaired ability to read but not spell due to an inability to perceive constituent letters but have no problem with the motor commands required to produce graphic representations.

Such dissociations between tasks based upon disruptions of peripheral perceptual and motor components do not seem particularly surprising. Much more intriguing are cases in which the dissociations between input and output tasks cannot be accounted for based upon disruptions of perceptual or motor processes. In these instances, researchers have been led to propose separate lexical representations for spoken word perception and spoken word production, as well as for written word perception and spelling.

**Evidence from Auditory Language Processing:** In the spoken language domain, patients classified as "word deaf" or "word meaning deaf" have been identified. These patients exhibit poor auditory comprehension but have preserved speech production. Peripheral deficits have been assumed to apply here with the deficits exhibited in word deafness resulting from a difficulty in perceiving the rapid acoustic changes necessary for speech perception. Word meaning deaf patients have been described as having difficulty in accessing semantic representations from phonology but not the reverse.

On the production side of spoken language, patients known as "apraxic" and "anomic" exhibit an impairment in their ability to produce speech but no difficulty in comprehending spoken language. The deficits in apraxic patients have been attributed to an inability to construct the motor programs necessary for spoken language production. Anomic deficits have
been attributed to an impaired ability to retrieve phonological representations for output from semantic representations.

The most striking data in the auditory domain showing separate input and output systems comes from deep dysphasic patients (e.g., MK of Howard & Franklin, 1987). These patients produce semantic errors in their repetition of single words along with an effect of imageability on repetition, and an inability to repeat nonwords. Deep dysphasia has been explained in terms of an inability to utilize direct connections between input and output lexical phonological representations as well as an inability to sublexically recode phonology from input to output. These patients, therefore, are forced to repeat words via a semantically mediated route which provides an opportunity for semantic errors as well as other semantic effects on repetition. This explanation requires that lexical representations for input and output phonological processing be separate. The fact that deep dysphasics produce semantic errors suggests that they are gaining access to the correct lexical representations to access semantics. A problem accessing the correct lexical phonological representation would likely result in phonologically related word errors and not semantic errors. If they have good access to the lexical representations for comprehension, then why would they have a problem producing them if the lexical representations are one and the same? Therefore, based upon this evidence, the separate lexicon view would seem more likely than the single lexicon view.

More recently, however, Martin & Saffran (1992) have presented a connectionist model of deep dysphasia which includes a single lexical phonological representation for both input and output. It is their argument
that the deficits observed in deep dysphasic patients are due to pathologically high levels of decay of phonological representations. Patients are forced to rely more heavily upon the semantic level of representation in repetition than normal and thus more semantic errors and semantically mediated effects occur. Thus, these researchers can account for patterns of performance in deep dysphasia without resorting to a dual lexicon model.

In the visual domain, a tradition begun by Dejerine (1892; see Shallice, 1988) distinguished two syndromes. One, alexia with agraphia involved a reading impairment with a concurrent writing deficit and the other, alexia without agraphia involved a reading impairment only. Dejerine assumed that there was a single visual word form system which was utilized for both reading and writing. It was his contention that alexia with agraphia resulted from damage to this word form center. Alexia without agraphia resulted from a disconnection of this intact word form center from the primary visual areas.

More recent evidence has distinguished a variety of reading and writing deficits. The following section outlines the theories and findings relevant to the single vs. dual lexicon debate.

**Classes of Lexical Orthographic Theories.** There are three general classes of orthographic lexicon theories. Although these same classes of theories are relevant to the debate in the auditory domain as well, the discussion here will be limited to visual word recognition and production. The first of these is the independent lexicon theory (Ellis, 1982; Monsell, 1987a; Patterson & Shewell, 1986). See Figure 2 for a representation of this type of model.
This theory holds that the pathways for accessing meaning and pronunciation from a visual input are separate from those used to access a graphemic output from meaning or pronunciation. In addition to having separate pathways, each has its own lexical representation (one for input and one for output). In this manner there are two abstract lexical representations for every word in a person's vocabulary, one for reading
and one for spelling. The only manner in which these two lexical systems are linked is through a semantic system. Therefore, for this class of theory, any relationship between reading and spelling deficits should be mediated by semantic representations. For example, reading and spelling deficits should occur for items of the same semantic category or word class. If an individual exhibits a correspondence between a reading and spelling deficit, it necessarily must be due to a disruption of the semantic representation for that item or set of items. Reading and spelling performance would be impaired for items which share those semantic features or representations which are damaged. Thus, categorical deficits should be seen. Additionally, a disruption of semantic representations would result in similar impairments in other domains (e.g., auditory language processing, picture naming). In such a case, factors such as the imageability of the items, word class, and frequency should be the sole determinants of the relationship between reading and spelling. These types of theories would predict that there should be no lexically based priming between reading and spelling.

The second type of general theory is the common lexicon theory (Allport & Funnell, 1981; Coltheart & Funnell, 1987). In contrast to the independent lexicon theories, this class of theories assumes that only one lexical representation is used to process both visual words and produce written or spelled output, see Figure 3.
Figure 3:

Model of Common Orthographic Lexicon Theory:

It is unclear as to whether or not the same pathways or procedures would be utilized for both visual word recognition and spelling. In any case, theories of this type presume that any impairment to a lexical representation should be seen in both reading and spelling. Thus, if the lexical representations for low frequency words seem to be unavailable to support reading in an individual then these same representations should be unavailable to support spelling. In fact, there should be a consistent one to one correspondence between items which cannot be read and those which cannot be spelled. In addition, these types of theories assume that there should be complete priming between reading words and spelling them.
The final general class of orthographic lexicon theories are the separate but linked theories (Monsell, 1987a; Monsell, 1987b; Newcombe & Marshall, 1980), see Figure 4.

Figure 4:
Model of "Separate but Linked" Lexicons Theory:

This type of theory is similar to the independent lexicon theory in that it presumes that there exist separate lexical orthographic representations for reading and spelling. These representations are linked via some form of sublexical connections between graphemic output and graphemic input. It is presumed that these connections function as a sort of orthographic rehearsal buffer (Monsell, 1987b). Although described in this manner, it does not seem necessary that the items continually cycle through this system. It is possible that when the system is stressed visual word inputs are automatically converted once to a spelling form via these sublexical
connections. Additionally, it is unclear as to why Monsell assumes that these connections would be sublexical. Presumably, sublexical connections between graphemic input and graphemic output would come into play in the case of copying written words or nonwords. If the sole source of the repetition priming effect came at a sublexical level then one would expect to find effects for both words and nonwords. As with the effects obtained with words, the Monsell (1987b) results for nonwords are equivocal. In one instance he obtains inhibition for repeated nonwords and in the other he finds no difference between repeated and non-repeated nonwords. However, due to the difference in the size of the repetition effects for words and nonwords (when they were obtained), Monsell states that "it seems unlikely that the whole of the repetition effect for words can be attributed to this response bias." (Monsell, 1987b, p.313). In this case the response bias is the tendency to respond "word" to items with some episodic familiarity. It is, therefore, likely that in the normal course of literacy, whole lexical items are linked between the input and output orthographic lexicons in addition to any links between sublexical units in graphemic input and graphemic output. Any relationships observed between reading and spelling performance would depend entirely upon whether the task is such that it requires utilization of these connections. What these requirements would be is not exactly clear, although Monsell hypothesizes that stressing the processing capacity of the system is enough. According to this theory, one may be able to show priming between input and output representations but not obligatorily. As for the separate but linked lexicon theories, it would seem that stimulus characteristics such as meaningfulness and frequency (and possibly word length) should account
for any relationships observed between impairments in reading and impairments in spelling due to the fact that the deficit would have to be at the only common component, the semantic system.

**Cognitive Neuropsychological Evidence for Independent Orthographic Lexicons.** Patients have been described who present with a specific impairment in their ability to read words that has been attributed to a deficit in lexical representation. These patients, known as pure alexics or letter-by-letter readers (Patterson & Kay, 1982; Warrington & Shallice, 1980), have a reading impairment which is characterized by increasing reading time with increasing word length. These patients are unable to read a word without first identifying its constituent letters. It has been suggested that these patients suffer from an inability to gain access to representations in the input orthographic lexicon from print (Warrington & Shallice, 1980). Their accurate but slow reading, however, is accomplished through a strategy which involves the utilization of the intact spelling or output orthographic lexical representations. Warrington and Shallice (1980) call this a reverse spelling strategy. Some letter-by-letter readers have relatively accurate spelling systems but impaired reading systems.

Data from letter-by-letter readers has been taken as evidence that separate lexical orthographic representations exist for input and output. This, however, presumes that the impairments exhibited by these patients are due to damage at the level of the lexical representation. If the locus of the impairment is at a level other than the input or output lexicon, then one could have patients who exhibit supposedly pure deficits yet still have a single orthographic lexicon. For example, in the case of letter-by-letter
readers, Warrington & Shallice (1980) suggested an inability to access input lexical orthographic representations. Their intact spelling abilities, however, does not preclude a common lexicon interpretation. One could argue that a common lexicon exists for reading and spelling and that these representations are accessed differently for the two tasks. So in the case of letter-by-letter readers, the input access route is damaged but the output route is intact. This access impairment presents itself as a pure deficit.

Pure agraphics exhibit a specific impairment in their ability to produce written output while maintaining their ability to read words relatively well. Beauvois & Derouesne (see Shallice, 1988 for a description) presented the case of a patient with an impairment in his ability to spell words with ambiguous phoneme-grapheme correspondences. Words which had unambiguous phoneme-grapheme correspondences were spelled correctly while words with greater phoneme-grapheme ambiguity were more likely to be spelled incorrectly. This patient wrote 100% of nonwords, 93% of low ambiguity words, but only 36% of high ambiguity words were spelled correctly. The fact that this patient was able to produce correct spellings for some words rules out a peripheral problem in writing as the locus of his impairment. The errors produced by this patient and by others of his type are graphemically plausible interpretations of the words' phonology. In contrast to his impaired spelling, this same patient was able to read 93% of nouns and adjectives correctly. The interpretation of such deficits has been that these patients have impaired output lexical orthographic representations. This impairment forces them to rely upon a sublexical route to produce a written output. Reliance upon this route results in poorer performance on words whose phoneme-grapheme
correspondence is ambiguous. However, similar to letter-by-letter readers, pure agraphic patients may suffer from an impairment in their ability to access graphemic output from intact lexical orthographic representations which are used for both reading and writing.

A type of patient known as a deep dysgraphic patient has also been described (Bub & Kertesz, 1982b). These individuals exhibit an inability to write nonwords, abstract words and function words. In addition to the difference between concrete and abstract words, these patients also produce semantic errors in their writing. These patients have no problem repeating these items they cannot spell and have no problems reading these items. Again, this dissociation between the ability to read words well and a profound impairment in the ability to spell words seems to support independent input and output orthographic lexicons.

Their inability to write nonwords suggests an impairment in utilizing a sublexical route to produce a written output. The fact that these patients do not exhibit an impairment in their ability to read these same words has been taken as evidence that the impairment is not semantically based. Researchers have presumed that the deficit in these patients lies at the level of lexical orthographic representations. Since writing and not reading was affected it was assumed that separate lexical representations for each existed. However, one can make a similar argument here as that made for pure agraphics. It is possible that the deficit does not lie at the level of the lexical orthographic representation but at the access level. These deep agraphic patients may suffer from an impairment in their ability to access common lexical orthographic representations from semantics for writing
but have no impairment in their ability to access these same representations for reading.

These presumed representational impairments which were interpreted within an independent lexicon theory can be accounted for within a common lexicon theory if the impairment is one of access and not representation. Hypothetically one can differentiate between an access and a representational impairment in that patterns of errors should tend to be much more consistent across items, tasks, and test sessions in the case of a representational impairment. An access impairment is less likely to show consistent errors across these same three instances.

Campbell (1987) presents two cases of developmental dysgraphia (RM and JM). When these patients were presented with items that they consistently misspelled, they were less likely to reject those items as misspellings as compared to control misspellings. Their performance in making spelling judgments to correctly spelled words (including words they consistently spell correctly and correctly spelled versions of their consistent misspellings) was within the normal range (RM: 89% correct on consistently correctly spelled words, 91% on correctly spelled control words; JM: 100% on consistently correctly spelled words, 92% on correctly spelled control words). The mean for controls was 94.7% for the correctly spelled items. Additionally, their spelling judgments to the control misspellings was within the normal range of performance (RM: 77%; JM: 70%; Control mean: 87.6%). Two of the normal subjects performed below 75% correct on the spelling judgments to the misspelled words. Thus the patients' poor performance on their own consistent misspellings was not due to an overall impairment in making spelling
judgments. The consistency of their misspellings (words classified as consistently misspelled were misspelled on every occasion they were presented) was interpreted as evidence that the impairment was at the level of the lexical representation. That is, there was something about the lexical representations for these items which was causing these patients to consistently produce misspellings as well as to accept these misspelled items as correct. It would seem simple to accommodate these results within a common lexicon theory. Both RM and JM have representations for the consistently misspelled items within their orthographic lexicon. For these items this is the only representation. Thus their spelling is consistently incorrect and they are more likely to misjudge the spellings of these items. However, these patients are quite capable of judging the spelling of correctly spelled items (even the correctly spelled versions of those words they consistently misspell). Their spelling judgment performance suggests that these patients also have lexical representations for the correctly spelled versions of these words available to them in their orthographic lexicon. If these patients have lexical representations for both the correctly spelled and the incorrectly spelled versions of consistently misspelled words in their lexicon, then Campbell argues one would expect that they would not exhibit consistency in their misspelling of certain words. If both representations are available in a single common lexicon then at least on some occasions the correctly spelled version of that words should be produced. Campbell (1987), therefore, feels that one must argue that separate input and output lexical representations exist for reading and spelling. Lexical representations for both the correct and incorrect spellings would be present within the input orthographic lexicon. Thus, spelling judgments
for correctly spelled words would be normal and for consistently misspelled words below normal in these patients. For the consistently misspelled items, only the misspelled representation would be present in the output orthographic lexicon.

It may be possible to account for Campbell's findings within a common lexicon theory. It is possible that words which are consistently misspelled actually have lexical representations for the misspelled version which are stronger and more easily activated than their correctly spelled counterparts. So both a correctly spelled and an incorrectly spelled lexical representation is present in the common lexicon. This would account for the patients poor performance at spelling judgments to their consistently misspelled words and preserved spelling judgments for correctly spelled items. The representation for the correctly spelled version corresponding to the consistently misspelled items, however, may not be sufficiently strong to support production in spelling. It can, therefore, never activate representations in graphemic output so consistent misspellings result for these items. In this manner one could accommodate both the consistency of the subjects' misspellings as well as their inability to detect these as incorrect in the face of good detection of correctly spelled versions within a common lexicon theory.

The data presented by Campbell (1987) was interpreted within an independent lexicon framework. As was argued above, these same data can be accounted for within a common lexicon theory with little problem. Therefore, there has been no overwhelmingly convincing neuropsychological data for independent lexicon theories presented to date.
The question remains as to whether there has been any convincing evidence in favor of common lexicon theories.

**Cognitive Neuropsychological Evidence for a Common Orthographic Lexicon.** Surface dyslexia is characterized by an impaired ability to read words with irregular spelling to sound correspondences in the face of preserved reading of regular words (e.g., boat) and legal nonwords (e.g., plim). When presented with irregular words for reading these patients produce regularization errors. This pattern of performance can be the result of damage to any of several components involved in the mapping of print to sound. In at least some cases of surface dyslexia, the locus of impairment has been found to be the disruption of representations within the orthographic input lexicon (Marshall & Newcombe, 1973).

Similarly, patients with surface dysgraphia have a selective impairment in their ability to produce a spelled output for irregular words. As with surface dyslexia, cases have been described which seem to locate the problem at the level of lexical orthographic representations (Beauvois & Derouesne, 1981; Roeltgen & Heilman, 1984; Baxter & Warrington, 1987). These two types of patients have an important bearing upon the issue of separate orthographic representations for reading and spelling. If the representations utilized for reading and spelling are separate then an individual exhibiting a disruption to lexical representations for one process or the other should not show a relationship between the words he is able to spell and those he is able to read. Since the representations utilized by the two processes are different, then any overlap in the words he cannot read and those he cannot spell would be due to chance factors. However, if the orthographic representations are the same for both reading and spelling
then an individual who has an impairment to those representations should show a relationship between the words misread and those misspelled.

Coltheart and Funnell (1987) presented the case of a surface dyslexic and surface dysgraphic patient, HG. HG is able to read 91% of nonwords and 98% of regular words, however, when irregular words are presented in a list of both regular words and nonwords he reads only 88% of mildly irregular words and 70% of highly irregular words. Highly irregular words are defined as words which contain multiple irregularities whereas mildly irregular words contain only a single irregular grapheme-phoneme correspondence (Shallice, Warrington, & McCarthy, 1983; see also Behrmann & Bub, 1992). Coltheart and Funnell (1987) gave HG a set of 214 homophones for reading comprehension. This task was administered twice. HG miscomprehended approximately 21% of these items. Surprisingly, HG made more errors on the regularly spelled homophones than on the irregularly spelled ones. Coltheart and Funnell's explanation for this difference was the following. When a presented homophone is regular HG is able to derive its phonology non-lexically from print and thus, either comes up with a correct response or a homophone confusion. When a homophone is irregular he cannot retrieve a non-lexical pronunciation so he is forced to succeed in lexical processing in order to comprehend these items.

From this set of 214 homophones which were given to HG for comprehension, Coltheart and Funnell (1987) selected the set of 171 regularly spelled homophones. These 171 items were divided into two sets. One set (Set A) consisted of 107 words which were defined correctly on both administrations of the reading comprehension task. The consistently
good comprehension was taken as an indication that the lexical orthographic representations for these words are intact. The second set (Set B) consisted of 64 words which were defined incorrectly at least once in the two administrations of the reading comprehension task. This was interpreted as indicating that the lexical orthographic representations for these words were to some degree compromised. Coltheart and Funnell (1987) compared HG's spelling performance for these two sets of items.

A model of reading and spelling which included a single set of lexical orthographic representations for reading and spelling would predict that spelling performance would be worse for the Set B items than for the Set A items even when effects of frequency were taken into account. Conversely, a model which included separate lexical representations for reading and spelling would predict that once the effects of word frequency are taken into account, there should be no relationship between membership in a particular set and whether an item can be spelled. In other words, whether or not an item can be read correctly does not predict whether that item will be spelled correctly above and beyond what is predicted by the frequency of that item. Regression analyses showed that even when frequency was accounted for, correctly read items were more likely to be spelled correctly than were incorrectly read items. This data would appear to provide evidence for the single orthographic lexicon hypothesis. However, it does not account for possible mediating factors other than frequency. It is possible that an additional impairment at the semantic level could account for the relationship between HG's reading and spelling performance. Factors such as concreteness or imageability would
need to be ruled out in order to make a stronger case for a common lexicon based upon this patient's data.

In a similar study, Behrmann and Bub (1992) presented the case of a surface dyslexic (MP) patient, and showed that this patient exhibited significant correspondence between items which he could read and those which he could spell. MP, as is indicative of surface dyslexia, exhibited an impairment in her ability to read irregular words. The degree of impairment in irregular word reading was related to the frequency of the items. She read 80% of high frequency irregular words, 62% of mid-frequency irregular words, and 40% of low frequency irregular words. In comparison, she read 95% of nonwords correctly. Behrmann and Bub (1992) constructed a set of 392 words containing 196 regular words and 196 irregular words drawn from a wide range of frequencies. These items were presented to MP for reading aloud and for spelling to dictation. She read the regular words significantly better than the irregular words and showed a significant effect of frequency on her irregular word reading but not her regular word reading. On the spelling to dictation task MP exhibited a similar pattern of performance. She spelled the regular words significantly better than the irregular words and exhibited a frequency effect on her spelling of the irregular words.

Although there is a striking similarity in MP's pattern of performance across these two tasks, these data are not sufficient to bear upon the common vs. independent lexicon issue. It is necessary to determine that MP's impairments, particularly her reading impairment, are occurring at a lexical level. That is, it is necessary to determine that the impairment is due to a disruption of lexical representations. If a common
lexicon is hypothesized then disruptions to lexical representations should result not only in impairments to both reading and spelling but to a significant correspondence between those specific items which are unreadable and those which are unspellable.

In order to address the issue of whether MP's deficit was at a lexical level, Behrmann and Bub (1992) examined MP's performance on a full report word superiority task. In this task, MP is presented with briefly presented and masked words and nonwords. The nonwords differed from the words by a single letter. The words varied in frequency. The subject is asked to report all of the letters they saw. Typically, normal subjects perform better with the word stimuli than with the nonwords. This is explained in terms of the influence of lexical representations for words which help subjects perceive these items. Nonwords do not have lexical representations and thus do not exhibit any benefit. Behrmann and Bub (1992) proposed that if MP's impairment in reading irregular words, particularly low frequency words, was a result of impaired lexical representations for these items, then MP should not show facilitation for these items over nonwords. MP did show an overall word superiority effect in that she reports more words correctly than nonwords. However, she did exhibit a decreasing word superiority effect as the frequency of the items decreases. This result was interpreted as evidence that MP's irregular word reading impairment is due to a deficit in the activation of lexical orthographic representations.

To address the issue of the consistency of performance between reading and spelling, Behrmann and Bub (1992) also examined the relationship between MP's reading of a set of 92 irregular words and her
spelling of these same words. As in the Coltheart and Funnell (1987) study, if a correspondence between reading and spelling can be found after the effects of frequency have been partialed out, a case can be made for a single lexical representation underlying reading and spelling. Sample Kappas were calculated between reading and spelling in order to assess the consistency of the performance on the two tasks. This analysis found moderate to good correspondence between performance on the reading task and performance on the spelling task for items in all of the frequency bands. Unlike Coltheart & Funnell (1987), Behrmann & Bub (1992) examined the contribution of other possible factors: modality (reading vs. writing), word length, and imageability. When frequency, word length, and imageability were removed MP's reading and spelling performance were virtually indistinguishable. This correspondence was taken as evidence that a single lexical orthographic representation underlies both reading and spelling. The results of Behrmann & Bub (1992) are probably the most convincing evidence to date for the common orthographic lexicon theory. If, however, this common lexicon theory is correct, then there should be some evidence of its effect in the performance of non-brain-damaged individuals.

Evidence from Neurologically Intact Subjects on Single vs. Dual Lexicons

The issue of single or dual orthographic lexicons has not been extensively studied in normal subjects. Monsell (1987b) presented some evidence both for and against the hypothesis that a single orthographic representation underlies reading and spelling. In an earlier unpublished study (Monsell & Banich, unpublished) he reports finding no evidence that lexical decision performance can be facilitated by writing a word without
viewing the written output. This can be taken as evidence that a common lexical orthographic representation does not underlie both reading and spelling. If it did, then any task which utilized an output lexical orthographic representation (e.g., spelling to dictation) should facilitate later visual word recognition performance. Monsell & Banich argued that this result could be accommodated either by the hypothesis that independent lexicons mediate the performance of the two tasks or that separate but linked lexicons exist but the linkage is for some reason not operating. The task utilized by Monsell and Banich involved the filling in of a missing word in a sentence frame. In all cases the sentence frame remained on the screen until the subject completed the item. Monsell suggested that the lack of a priming effect may have been due to the concurrent processing of text (the sentence frame) other than the target word. Monsell (1987b) attempted to replicate the earlier findings in a second experiment. In this experiment subjects saw a sentence appear on the screen for which they had to fill in a word. In some cases this word was provided (i.e., it appeared on the computer screen) whereas in other cases they were required to write the missing word without viewing their written output. In addition, in some cases the sentence frame remained on the computer screen until they completed their response while in others it was removed. Subjects showed significant facilitation both from previously viewing the target word as well as from writing it blind. Significant facilitation for the writing blind condition was only found in those cases where the sentence frame remained on the screen until the subject responded. Finding significant facilitation between spelling a word and later viewing that word contradicts the Monsell & Banich findings and lends support to the common lexicon
hypothesis. However, the fact that the facilitation occurred in a particular condition makes this interpretation much more difficult. Monsell (1987b) interpreted this as evidence for separate but linked lexicons. It was his contention that writing does not automatically activate representations in the input orthographic lexicon but that such activation can occur. When processing capacity is stressed (as is the case when text must be concurrently processed) then subjects "exploit the temporary storage capacity provided by the sublexical output - input loop" (Monsell, 1987b, p. 313). In an additional experiment utilizing the same procedures except that in one priming condition subjects looked at their own written output, Monsell (1987b) obtained similar results. He found significant facilitation when subjects saw the word as well as when they wrote the word blind and their processing capacity was stressed (i.e., concurrent text processing as previously described). However, no facilitation was obtained when subjects wrote the words blind with no capacity manipulation, even when they subsequently viewed their own written output. Again, this data was taken as evidence that input lexical orthographic representations and output lexical orthographic representations are separate but linked together. Under conditions of decreased capacity, subjects utilize these links as a storage mechanism and thus facilitation results.

It is, however, unclear what to make of Monsell's (1987b) findings. The previously reported data from Monsell & Banich contradicts the newer results. Unfortunately the experiments were reported in a book chapter which does not allow for the extensive description of methodological and statistical procedures. Without this information it is impossible to
determine which of the sets of data to believe. This fact alone requires that the issue be re-examined.

Although not specifically interested in the independent vs. common lexicon issue, Jacoby and Hollingshead (1990) conducted a study which provides evidence that a single representation underlies both reading and spelling. In a long-term priming paradigm, Jacoby and Hollingshead found that visual presentation of correct and incorrect spellings at study significantly influenced performance on a later spelling to dictation test of the same words. If the subject was presented with a correctly spelled word to read at study, they were more likely to produce the correct spelling of that word as compared to spelling a previously unstudied word. In contrast and more surprisingly, presentation of an incorrectly spelled word at study significantly lowered the probability that the word would be correctly spelled as compared to the new words. Presentation of correctly spelled words at study also speeded subjects' later performance on the spelling to dictation test although previously viewing incorrectly spelled words at study did not have a significant influence on the speed at which subjects later spelled these words.

Although intriguing, it is not clear exactly how to explain the results of Jacoby & Hollingshead (1990). There are two possible explanations. The first is that lexical representations for commonly misspelled words are present within a common orthographic lexicon. This incorrect representation gets a boost in activation when it is presented during the study phase and so is more likely to be produced during the spelling test (see the discussion of Campbell (1987) above for further detail on this issue). The second possibility is that subjects are not exhibiting facilitation
from a pre-existing lexical representation but are constructing a lexical representation for the misspelled item on-line, presumably both in a reading and a spelling lexicon. Although the creation of an on-line lexical representation for viewed misspelled words may occur automatically and unconsciously, it does not require that common lexical representations for reading and spelling exist. This is similar but not equivalent to the argument that subjects are performing the task based upon specific episodic recollection of the previously studied items. However, in Jacoby & Hollingshead (1990), later recognition of the studied items was not predictive of spelling accuracy. Presumably, if subjects were basing their spelling of the items upon their recollection of its presentation at study then some relationship between recognition and spelling accuracy should be apparent.

The experiments presented below examined the relationship between the lexical representations involved in reading and spelling. These tasks investigated whether it is possible to prime orthographic representations from reading to spelling and vice versa. The results of these experiments are used to provide evidence for or against a dual lexicon view of the orthographic system.

As mentioned above, previous research has approached this issue by attempting to show long-term priming from spelling to reading and vice versa. Both the Monsell (1987b) and the Jacoby and Hollingshead (1990) studies utilized this paradigm. The first two experiments presented here utilize this long-term repetition priming paradigm while the third involves repetition priming over shorter intervals.
Experiment 1

The purpose of this experiment was to examine the influence of reading and spelling (without viewing the written output) on subjects' later reading performance. Equivalent facilitation for read and spelled items would provide evidence for a single orthographic representation mediating both reading and spelling. Facilitation for read items but not spelled items would provide evidence for separate orthographic representations for reading and spelling and no connections between the two lexicons, because facilitation occurred only when a visual stimulus was processed at both study and test. An intermediate amount of facilitation for spelled items vs. read items could suggest that the orthographic representations for reading and spelling are separate but in some way linked.

The four conditions included in this experiment were READ, SPELL, NAME, and NONSTUDIED. Previous evidence indicates that priming will be found for the READ condition. Weldon (1991) found a 17% priming effect on a perceptual identification task, from reading a word at study. In the SPELL condition, subjects saw a picture and wrote the name without being able to view their written output. The NAME condition was included as a control because priming might occur in the SPELL condition due to seeing a picture and internally generating its name. Previous research has shown that internally generating the name of an item provided about a 6% priming effect. Therefore, in the SPELL condition, a priming effect which approximates that obtained from naming a picture would not be significant evidence for a single lexicon as this is the level of priming one would expect from naming a particular item.
The aim of this study was to examine effects at the level of the orthographic lexicon(s). The reading and spelling systems are assumed to share a common semantic component. Thus, in order to insure that any effects obtained are the result of processing at the level of the lexicon, one needs to control for semantically mediated effects. This issue was mentioned previously in relation to the interpretation of the cognitive neuropsychological evidence. The long-term repetition priming paradigm chosen for Experiment 1 was chosen in order to address concerns about semantically mediated effects. In studies examining the influence of semantic variables on priming in the standard implicit memory paradigms (Roediger & Challis, 1992; Roediger & McDermott, 1992a) synonyms, associates, category coordinates, and visually similar words produced no priming in a word stem completion task. Therefore, the long-term priming paradigm seems to be free of any semantically mediated effects and thus a good tool for examining the relationship between reading and spelling at the lexical level.

Method

Subjects

Forty-eight subjects from the Rice University Psychology Department subject pool participated in this experiment. These subjects received course credit for their participation.

Materials

The experimental stimuli consisted of 96 items chosen from the Snodgrass & Vanderwart (1980) pictures. Twenty-four items were used in each of the four study conditions (READ, SPELL, NAME, and
NONSTUDIED). All of the items appeared in each of the study conditions across subjects.

**Design and Procedure**

A one-way within subjects design with four levels was used in this experiment with study condition (READ, SPELL, NAME, and NONSTUDIED) as the levels. Items were counterbalanced across conditions across subjects. This resulted in four different study lists for each condition (READ, SPELL, and NAME). The order of study conditions was selected randomly for each subject. Within a study condition, trials were presented in a different random order for each subject.

Based upon the results of pilot studies, each of the study conditions was presented blocked such that a subject was only making one type of response at a time (reading words, naming pictures, or spelling the names of pictures without viewing the output). In all conditions, subjects were first presented with a ready prompt. Following the prompt, either a word (READ condition) or a picture (SPELL and NAME conditions) appeared on the computer screen. In the READ condition, subjects were asked to read the words to themselves. In the SPELL condition, subjects were asked to write the name of the picture on a piece of paper without viewing their output. In this condition subjects kept their hand inside a box containing paper and were not allowed to see what they were writing. This was monitored by the experimenter. In the NAME condition, subjects were asked to name the pictures to themselves.

In all cases, after subjects had completed the task for a particular study condition, they were asked to decide how pleasant they considered
each object to be and press that number on the computer keyboard. The scale was from 1 (very unpleasant) to 5 (very pleasant). After subjects made their pleasantness decision the next trial would begin. The pleasantness judgments were included to better equate the level of processing of the items in all of the study conditions.

After the study phase, subjects had a 10 minute filled delay during which they wrote U.S. state capitols and U.S. presidents. Following this filled delay, subjects completed a perceptual identification task. This task consisted of 96 trials (24 from each of the three study conditions plus 24 nonstudied items). A central fixation point was presented to the subjects to signal the start of each trial. Following the fixation a forward mask was presented followed by the briefly presented target item and a backward mask. Subjects were asked to identify the presented item and write their responses on a response sheet. Prior to the perceptual identification test, subjects were given a practice perceptual identification test in order to familiarize them with the task and to assign them to one of three presentation rates for the actual test (slow (24 ms per item), medium (30 ms per item), or fast (35 ms per item)). In this practice test, subjects were presented with 20 items at the medium presentation rate (30 ms). Subjects who obtained two or fewer errors ($\leq 10\%$ errors) were assigned to the fast presentation rate (24 ms). Subjects who obtained 3-4 errors (15-20% errors) were assigned to the medium presentation condition (30 ms). Subjects who obtained 5 or greater errors ($>25\%$ errors) were assigned to the slow presentation condition (35 ms).

After the completion of the perceptual identification task, subjects were asked to name the pictures from the NAME study condition and read
the words out loud from the READ study condition. This was done to check the consistency between the experimenter driven target response and the responses given by the subject (unvoiced during the study condition). Consistency of subject responses with experimenter expectations in the SPELL condition can be checked with the subjects written output. Any deviations from the target responses will be removed from any subsequent data analysis. Since there is no objective test of subjects responses in the NAME and READ conditions during the study phase, it is necessary to check this post-test. It is most likely that of the two (READ and NAME) any deviations in response will occur in the NAME condition

Results

Prior to analyzing these data, any items which had been misspelled during the SPELL study condition or had been misnamed or misread on the subsequent naming and reading check were removed from the analyses. Subjects whose performance fell outside of our upper (over 90% correct overall) and lower boundaries (less than 20% correct overall) were excluded from our analysis. This resulted in 27 subjects being removed from the data analysis. The data presented below are from the 48 subjects remaining whose performance fell within our performance range.
Table 1

Percent Correct and Priming Proportions by Condition for Experiment 1:

<table>
<thead>
<tr>
<th></th>
<th>Study Condition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Read</td>
<td>Spell</td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>65.4%</td>
<td>60.1%</td>
</tr>
<tr>
<td>Priming</td>
<td>.075</td>
<td>.023</td>
</tr>
</tbody>
</table>

Table 1 presents the percent of items correct in each study condition and the difference between the accuracy of perceptual identification of items from various study conditions and the accuracy of perceptual identification of previously nonstudied items. Analysis of these priming proportions revealed a statistically significant main effect of condition, $F(2,47)=3.26$, $MS_{e}=.0102$, $p=.0428$.

Post-hoc pairwise comparisons utilizing Tukey's studentized range test revealed that priming in the READ condition significantly differed from priming in the SPELL conditions, Critical $t(94)=3.368$, $MS_{e}=.0102$, $p=.05$. Priming in the READ condition did not differ significantly from priming in the NAME condition. In addition, priming in the SPELL and the NAME conditions were not significantly different from each other.

Discussion

The results of Experiment 1 showed that, as expected, reading a word at study significantly facilitated accuracy in a later perceptual identification task thus resulting in facilitation in performance on items
read at study as compared to the nonstudied baseline. However, spelling that word without viewing it did not facilitate later perceptual identification of the word in comparison to a nonstudied baseline. This result supports the contention that lexical orthographic representations used in input and output tasks are separate and are not linked. This finding contradicts theories which have been previously proposed about the structure of the input and output orthographic lexicons based upon studies with brain-damaged patients (Berhmann & Bub, 1992). This will be discussed in more detail in the General Discussion below. Although the amount of priming obtained in the READ condition differed significantly from that obtained in the SPELL condition, priming in the NAME condition did not differ significantly from the amount of priming obtained in either the READ or the SPELL condition.

As previously mentioned, Weldon (1991) reported significant priming (as compared to a baseline condition) from naming pictures to reading words in a perceptual identification task. The priming effects reported by Weldon were slightly more than twice the size of the effects reported here. However, the pattern of the effects (i.e., half as much priming from naming a picture as from reading a word) is similar to those reported by Weldon (1991). The overall lower levels of priming could be the result of the delay between the study and test periods.

Experiment 2a

Experiment 1 examined the influence of spelling on subsequent reading performance. The present experiment reversed this order, examining the influence of reading on spelling. Few researchers have examined priming from reading to spelling. An exception is the Jacoby
and Hollingshead study (1990) discussed earlier. However, this study did not contrast size of priming effects from reading and spelling on spelling. The spelling task utilized by Jacoby and Hollingshead (1990) (i.e., spelling to dictation) did not allow for a very fine-grained analysis of spelling time. A better measure of reaction time in a spelling task is the spelling-probe task developed by Kreiner (1992). Given normal subjects' near perfect performance on spelling to dictation tasks, a RT measure allows for a possibly more sensitive gauge of priming effects. The spelling-probe decision task involves the auditory presentation of a word followed by the presentation of a visual letter. Subjects are asked to decide as quickly and as accurately as possible whether the presented letter appears in the spelling of the auditorily presented word. Kreiner (1992) has shown that this task is sensitive to factors which influence spelling to dictation tasks, such as word frequency and polygraphy (i.e., the number of letters or combination of letters which can be utilized to represent a given phoneme), and thus does involve the utilization of the spelling system. In addition it provides a task in which reaction times are recorded for a single decision process, which mimics the lexical decision tasks used previously to assess reading. It also circumvents the need for complex motor output on the part of the subject which may cause increased variability in subjects' spelling times. In addition to the spelling-probe task, subjects' performance on a subsequent spelling task in which they are asked to provide the missing-letter of a presented word was also examined. This missing-letter test was included as an additional test of spelling for comparison to the results of the spelling-probe task. This test was felt to adequately tap the spelling process as well as also allowing for the collection of RT data.
This experiment compared reading vs. spelling on later spelling performance. Subjects were presented with words to read, pictures to name, or asked to spell the names of pictures without viewing their written output at study. As in Experiment 1, the picture naming condition was included as a measure of the amount of priming expected from internally generating the name of a pictured item. Later, subjects were presented with these words and with new words for spelling-probe decisions (Kreiner, 1992) or missing-letter decisions.

Method

Subjects

Sixty-four subjects from the Rice University Psychology Department subject pool participated in this experiment. Course credit was given for their participation in this experiment.

Materials

Ninety-six stimulus items were chosen from the Snodgrass & Vanderwart (1980) norms. Only items whose naming consistency was 90% or above were chosen.

Design and Procedures

As in Experiment 1, four study conditions (READ, SPELL, NAME, and NONSTUDIED) were used in this experiment. Items were counterbalanced across conditions across subjects. This resulted in four different study lists for each condition (READ, SPELL, and NAME). The order of study conditions was selected randomly for each subject. Within a study condition, trials were presented in a different random order for each subject.
Like Experiment 1, each of the study conditions was presented blocked such that a subject was only making one type of response at a time (reading words, naming pictures, or spelling the names of pictures without viewing the output). In all conditions, subjects were first presented with a ready prompt. Following the prompt, either a word (READ condition) or a picture (SPELL and NAME conditions) appeared on the computer screen. In the READ condition, subjects were asked to read the words to themselves. In the SPELL condition, subjects were asked to write the name of the picture on a piece of paper without viewing their output. In this condition subjects kept their hand inside a box containing paper and were not allowed to see what they were writing. This was monitored by the experimenter. In the NAME condition, subjects were asked to name the pictures to themselves.

In all cases, after subjects had completed the task for a particular study condition, they were asked to decide how pleasant they considered each object to be and press that number on the computer keyboard. The scale was from 1 (very unpleasant) to 5 (very pleasant). After subjects made their pleasantness decision the next trial would begin. The pleasantness judgments were included to better equate the level of processing of the items in all of the study conditions.

Of the total pool of 96 items, subjects were presented with 72 items at study (24 READ, 24 SPELL, and 24 NAME) with the remaining 24 items serving as nonstudied items. Each study condition was presented blocked separately so that at any one time during the study phase, subjects were only reading words, naming pictures, or writing the names of pictures without viewing the output. The pool of 96 items was
counterbalanced across subjects so that all items occurred in all study conditions including the nonstudied condition. Each subject received a different random order of study condition blocks.

Following a 10 minute filled delay, subjects completed both a spelling-probe decision task and a missing-letter decision task. The order of test type (spelling-probe or missing-letter) was counterbalanced across subjects such that half of the subjects completed the spelling-probe task first and half completed the missing-letter task first. In both of these tasks, subjects were presented with a ready prompt followed by the auditory presentation of a word. Immediately after the presentation of the auditory word, subjects saw either a single letter appear on the computer screen (spelling-probe task) or a visual word with a letter missing (missing-letter task). The missing-letter's position was held by a space in the visually presented word.

In the spelling-probe task, subjects were asked to decide as quickly as possible whether or not the presented letter appeared in the heard word when that word was written. Half of the spelling-probes did appear in the word (positive trials) and half of the probes did not appear in the word (negative trials). (Across subjects, items in the spelling-probe task were counterbalanced across "yes" and "no" responses such that all items appeared in both "yes" and "no" trials.) Subjects were to simply say "yes" or "no" and their response latency was recorded by a voice activated key and the actual response (yes or no) was recorded on a scoring sheet by the experimenter.

In the missing-letter task, subjects were asked to decide as quickly as possible what letter was missing from the word. Subjects were asked to say
the letter that was missing and again their response latency was recorded by a voice activated key and the actual response was recorded by the experimenter.

Of the twenty-four items in each study condition, 12 of these were presented to subjects in the spelling-probe task and 12 in the missing-letter task. Thus, in each task (spelling-probe or missing-letter) a typical subject was presented with 48 critical trials (12 READ, 12 SPELL, 12 NAME, and 12 NONSTUDIED) along with 130 filler trials. Items were also counterbalanced across task (spelling-probe or missing-letter) such that across subjects items appeared both as spelling-probe trials and missing-letter trials. Thus over two tasks, a single subject would complete 178 trials per task (12 READ, 12 SPELL, 12 NAME, 12 NONSTUDIED, and 130 FILLERS).

After completing the spelling-probe and the missing-letter task, subjects were asked to name the pictures and read the words from those corresponding study conditions. This was done to check the consistency between the experimenter driven target response and the responses given by the subject (unvoiced during the study condition) for the same reasons as those laid out for Experiment 1 above.

Results

Prior to analyzing these data, any items which had been misspelled during the SPELL study condition, or had been misnamed or misread on the subsequent naming and reading check were removed from the analyses. Trials corresponding to voice-activated key errors were removed from the data. Reaction time data presented below correspond to correct spelling-probe or missing-letter task responses.
Table 2 provides the mean reaction times and error rates and priming scores for each of the study conditions by test type (spelling-probe or missing-letter). Error rates were practically zero in all conditions for both the spelling-probe and the missing-letter task and therefore were not analyzed.

Table 2  
**Mean Reaction Times, Error Rates, and Priming Scores by Condition for the Spelling-probe and Missing-letter Tasks:**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean RT</th>
<th>Error Rate</th>
<th>Priming RT (Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>753</td>
<td>0</td>
<td>-4 (0)</td>
</tr>
<tr>
<td>Spell</td>
<td>736</td>
<td>0</td>
<td>-21 (0)</td>
</tr>
<tr>
<td>Name</td>
<td>741</td>
<td>0</td>
<td>-16 (0)</td>
</tr>
<tr>
<td>Nonstudied</td>
<td>757</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean RT</th>
<th>Error Rate (%)</th>
<th>Priming RT (Error %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>730</td>
<td>0</td>
<td>-14 (0)</td>
</tr>
<tr>
<td>Spell</td>
<td>728</td>
<td>0.13</td>
<td>-16 (0.13)</td>
</tr>
<tr>
<td>Name</td>
<td>733</td>
<td>0</td>
<td>-11 (0)</td>
</tr>
<tr>
<td>Nonstudied</td>
<td>744</td>
<td>0</td>
<td></td>
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</tbody>
</table>
For reaction times, the missing-letter task did not produce significant levels of priming in the facilitation of performance in the various study conditions as compared to the nonstudied condition (all p's > .11). For the spelling-probe task, a marginally significant priming effect for reaction times in the SPELL condition relative to the nonstudied condition was obtained ($t(63)=-1.92$, $p=.0595$). None of the other conditions produced significant priming. However, when the amount of priming observed in each condition (READ, SPELL, and NAME) was compared to that observed in the others, no significant differences in the amount of priming were obtained (all p's > .11).

**Discussion**

Although not conclusive, it would appear that the results of this experiment provide at least some information related to the representations used in reading vs. spelling. Greater but non-significant facilitation of studied over nonstudied was observed for items which had been previously spelled without viewing the output. Reading an item at study produced very little facilitation in later spelling-probe performance. This hints at the possibility that representations within input and output orthographic lexicons are indeed separate.

This experiment also points out the relative sensitivity and usefulness of the spelling-probe task in studying these effects. It had been thought that the missing-letter task might provide a more natural test of spelling ability yet no significant priming effects were obtained in this task. It appears that the missing-letter task may be more heavily weighted towards reading processes rather than spelling processes, contrary to previous expectations.
Interestingly, this would suggest that in such tasks like spell checking, reading representations play as important a role as spelling processes.

Although marginally significant priming from spelling was obtained in the spelling-probe task, the amount of priming did not differ significantly from that in reading or naming. Therefore, though suggestive, this experiment does not provide conclusive evidence as to the level of representation underlying the priming effects obtained with the spelling-probe task. However, the marginal effect does suggest that a reliable result might be obtained with a more powerful analysis. The subsequent experiment was designed to re-examine the influence of reading vs. spelling on later spelling using the spelling-probe task and modifying the experimental design to try and maximize the ability to detect an effect.

Experiment 2b

This experiment differed from Experiment 2a in three ways. First, it utilized only the spelling-probe task at test. Second, all spelling-probe responses to the critical trials were positive responses (i.e., probe letters occurred in the corresponding critical items). Thirdly, the delay between the study phase and the test phase was eliminated.

Method

Subjects

Twenty-four subjects from the Rice University subject pool participated in this experiment. These subjects received course credit for their participation.

Materials

The same materials utilized in Experiment 2a were employed in this experiment.
Design and Procedures

The design and procedures in this experiment were the same as those employed in Experiment 2a with the following modifications. First, only the spelling-probe task was used to measure spelling performance in the test phase. Thus, each subject completed a total of 226 trials (24 READ, 24 SPELL, 24 NAME, 24 NONSTUDIED, and 130 FILLER TRIALS). Second, spelling-probe responses in all of the critical trials (READ, SPELL, NAME, and NONSTUDIED) were all "yes" responses. "No" responses occurred only in filler trials. Lastly, there was no delay between study and test. Immediately after completing the study phase, except for time required to instruct the subject, subjects began the spelling-probe test phase.

Results

Prior to analyzing these data, any items which had been misspelled during the SPELL study condition, or had been misnamed or misread on the subsequent naming and reading check were removed from the analyses. Trials corresponding to voice-activated key errors were removed from the reaction time data. Reaction time data presented below correspond to correct spelling-probe responses.

Table 3 provides the mean reaction times and error rates and priming scores for each condition.
<table>
<thead>
<tr>
<th>Study Condition</th>
<th>Read</th>
<th>Spell</th>
<th>Name</th>
<th>Nonstudied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time</td>
<td>687</td>
<td>684</td>
<td>710</td>
<td>704</td>
</tr>
<tr>
<td>Priming</td>
<td>-16.7</td>
<td>-19.7</td>
<td>6.54</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion</td>
<td>0.05</td>
<td>0.069</td>
<td>0.069</td>
<td>0.086</td>
</tr>
<tr>
<td>Priming</td>
<td>-0.027</td>
<td>-0.017</td>
<td>-0.017</td>
<td></td>
</tr>
</tbody>
</table>

**Analysis by Subjects:**

Analysis of the reaction time data from Experiment 2b revealed a significant main effect of condition, $F(2,23)=4.44, \text{MS}_e=1114.426, p=.0172$. Significant priming was obtained for items which had been spelled at study compared to previously unstudied words, $t(23)=-2.133, p=.0438$. Priming for items which had been read at study and those which had been named at study did not reach a statistically reliable level, ($t(23)=-1.45, p=.1605$; and $t(23)=0.57, p=.5734$, for read and name respectively). Post-hoc pairwise comparisons were conducted using Tukey's studentized range tests. These comparisons revealed that the priming obtained for spelled items was significantly greater than the priming for named items,
Critical $t(46)=3.425$, $M_{SE}=1114.426$, $p=.05$. The priming obtained for read items did not differ significantly from that obtained by spelled items nor from named items. However, examination of the number of subjects showing facilitation in the READ and SPELL conditions revealed that only 10/24 subjects showed facilitation in the READ condition (range -132 - 69) whereas 16/24 subjects showed facilitation in the SPELL condition (range -82 - 62).

As can be seen in Table 3, error rates for this task were relatively low. Analysis of the error data revealed no statistically significant effect of condition, ($p=.6393$).

**Analysis by Items**

Re-analysis of the data averaged across items revealed no statistically significant effects of condition for either the reaction time or the error rate priming data, (all p's > .1).

**Discussion**

Significant priming from the baseline nonstudied condition was obtained from previously spelled items in this task. Also, similar to Experiment 2a, none of the other conditions produced significant amounts of priming. These results suggest that the representations used in reading and those used in spelling are separate. Complicating the matter, however, both in Experiment 2a and in 2b, the amount of priming produced from spelling a word did not differ from that produced by reading that word. However, as stated above, less than half of the subjects tested showed any priming from previously reading the items. This is below what would be expected by chance. This contrasts with spelling the items which resulted in 2/3 of the subjects exhibiting facilitation. However, the results of this
experiment are far from conclusive. The analysis by items revealed no statistically reliable priming effects in any of the conditions for either the reaction time or the error rate priming data.

For the first time in the present experiments, performance for previously named items was actually slightly worse than performance for previously nonstudied items. This pattern of results more closely resembles what has usually been obtained in long-term priming studies, (i.e., significantly smaller effects of picture naming at study on tests of implicit memory for visual words than study conditions involving visual words) (Roediger & McDermott, 1993; Roediger & Weldon, 1987; Weldon, 1991). It can, therefore, be determined that any effect obtained for spelled items in this experiment is not due to internally generating that item's name. Again, it must be stressed that the general inconsistency of these results does not provide strong evidence for or against either the independent or common lexicon theories. Perhaps, priming effects might be enhanced if the period between prime and target repetitions was much shorter than those yet utilized.

Experiment 3

The previous experiments have examined the influence of reading and spelling an item at study on later reading and spelling performance. All of these experiments have utilized a long-term priming paradigm. It is possible that any interactions between reading and spelling may only be apparent at intervals which are much shorter than those explored thus far. The reasons behind this assumption will be laid out in more detail below. The subsequent experiment examined the relationship between reading and spelling utilizing a short-term priming paradigm. This short-term priming
paradigm may be particularly helpful in distinguishing a separate but linked lexical organization from the common lexicon and independent lexicon theories.

This experiment examined priming effects from spelling to reading and vice versa in a repetition priming task at short prime-target intervals. Thus, it allowed the comparison of priming effects within (read - read and spell - spell) and across (read - spell and spell - read) reading and spelling. In addition, this experiment also examined the effect of the number of intervening items between repetitions (lag) on the priming obtained in each task.

Although examining priming effects between reading and spelling over a much shorter time course than the previous experiments, the time course examined in the present experiment is on the order of seconds even at the shortest prime-target lag. This length of time should, seemingly, be more than enough for any spread of activation between representations to have reached its maximum. The effects examined over the various lags in this experiment are, therefore, presumed to be of the patterns of decay of activation over the various conditions (read-read, spell-spell, read-spell, and spell-read). Each of the three theories do make differential predictions as to the pattern of activation decay across lags. These predictions are discussed below.

A common lexicon theory would predict that the pattern of lag effects should be similar in all of the conditions. Given that they presumably activate the same lexical orthographic representations, a common lexicon theory would not presume differential rates of decay. Therefore, this theory would predict no interaction between condition and
lag. The common lexicon theory would, also, seem to predict similar overall levels of priming between conditions.

A "separate but linked" lexicon theory (Monsell, 1987b), predicts different patterns of lag effects across the various conditions. Specifically, the priming from reading to reading or from spelling to spelling (i.e., within a lexicon) should be more stable than that observed from reading to spelling or spelling to reading (i.e., between lexicons). This differential stability within and between lexicons would, therefore, result in a slower rate of decay of priming in the two "within" lexicon conditions (read-read and spell-spell) as compared to the two "between" lexicon conditions (read-spell and spell-read). This theory would also predict that overall levels of priming should be lower in the "between" lexicon conditions as compared to the "within" lexicon conditions. Priming observed in the "between" conditions (read-spell and spell-read) would still be predicted to be significantly greater than zero.

It is not particularly clear as to what pattern of lag effects would be predicted by an independent lexicon theory. The most likely prediction would be that two completely independent lexicons would operate on completely different principles. Thus, overall levels of priming within each lexicon, and the patterns of decay across lags would be expected to be different. It is also possible, however, that since they both represent lexical orthographic information, both lexicons might operate in a similar manner. This would presumably result in similar overall levels of priming and patterns of decay across lags. The main hallmark of an independent lexicon theory, however, would be a complete lack of priming between lexicons (read-spell and spell-read) in the presence of significant within
lexicon priming (read-read and spell-spell), irrespective of the patterns of decay.

Method

Subjects

Twenty-four subjects from the Rice University Psychology Department subject pool participated in two 1 hour sessions approximately three days apart for this experiment. Subjects received course credit for their participation in this experiment.

Materials

Four hundred-eighty words from the Oxford Psycholinguistic database were used in this experiment. Experimental items were counterbalanced across conditions and lag.

Design and Procedure

A 3 (prime type, read, spelled, nonstudied) x 2 (task type, lexical decision or spelling-probe) x 5 (lag, 1, 2, 5, and 10 ) within subjects design was used in this experiment. All subjects completed six experimental conditions (READ-READ, SPELL-READ, READ-SPELL, SPELL-SPELL, READ only, and SPELL only) across the two sessions. Each subject completed two experimental sessions with 800 trials in each session (40 READ-READ, 40 SPELL-READ, 40 READ-SPELL, 40 SPELL-SPELL, 40 READ only, and 40 SPELL only, plus 240 NONWORDS and 160 FILLER trials).

In the READ-READ condition, on all trials, subjects were presented with a word visually on the screen and were asked to make a lexical decision to that word. The experimental words appeared twice within a
session at various lag intervals (1, 2, 5, and 10). The intervals represent the number of items intervening between the presentation of an experimental item and its repetition. Ten of the READ-READ items within a session were repeated at each level of prime-target lag. Items at the various lags were counterbalanced across subjects. The measures of interest were the number of errors and the reaction times for the repeated items.

In the SPELL-READ task, subjects were presented with an auditory word followed by a visual letter. They were then asked to decide if that letter appeared in the written version of that word. Following the spelling-probe decision at various prime-target intervals (1, 2, 5, and 10 items), subjects were presented with a visual word and were asked to make a lexical decision to that word. As in the READ-READ condition, the experimental items were repeated at the various levels of prime-target lag (1, 2, 5, and 10).

In the READ-SPELL condition, subjects were first presented with a visual word for lexical decision. At various intervals (1, 2, 5, and 10 items) following their lexical decision response they were presented with an auditory word and a visual letter for a spelling-probe decision as previously described.

In the SPELL-SPELL condition, subjects were presented with auditory words and visual letters for spelling-probe decisions only. Again, at various prime-target lags items were repeated for a second spelling-probe decision. For the various repetitions, although the correct response remained the same across the two repetitions (i.e., two "yes" responses or two "no" responses), the actual probe letter differed on the two
presentations. For example, a typical "yes" pair might consist of the auditory stimulus ZEBRA followed by the letter "A" on the first trial and by the letter "E" on the second trial. The letter presented on the first trial of a "yes" pair always came from a position farther along in the word than the letter presented in the second trial of that pair. This was done to insure that subjects had always spelled the word at least that far before making a response.

Within an experimental session, trials were a mix of all of the conditions. Additionally, nonwords were also repeated so as not to confound repetition with lexical status and filler spelling-probe trials were added in order that an equal number of spelling-probe and lexical decisions were made during a session.

Results

Prior to analyzing the data, reaction times for the error trials were removed from the analysis. Reaction times for correct and incorrect target trials corresponding to incorrect prime trials were also removed from the reaction time analysis. Thus, the reaction time data correspond only to instances in which both presentations (prime and target) resulted in correct responses. In addition to this, it was noticed during the analysis phase that, due to experimenter error, a significant set of items was accidentally omitted from two conditions (60 items total, 40 from the READ only condition and 20 from the SPELL only condition). Therefore, the data discussed below will be based upon analyses with these particular items removed from all conditions. Analyses with these items included in the data produced similar results to those reported below.
Analysis by Subjects

Reaction Time Analyses. Table 4 presents the mean reaction times, error rates and priming scores for the various conditions across all lags. All reaction times and error rates for the four repeated conditions correspond to targets. Priming scores are in relation to the baseline conditions where an item was either read once or spelled once. The READ ONCE condition was used as the baseline for the READ-READ and SPELL-READ conditions whereas the SPELL ONCE condition was used as the baseline for the SPELL-SPELL and READ-SPELL conditions.
Table 4
Mean Reaction Times and Error Rates by Condition across Lag in Experiment 3:

<table>
<thead>
<tr>
<th></th>
<th>Lag</th>
<th></th>
<th></th>
<th></th>
<th>Mean Across Lags</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Read-Read Reaction Time</td>
<td>735</td>
<td>670</td>
<td>656</td>
<td>633</td>
<td>650</td>
<td>652</td>
</tr>
<tr>
<td>Error Rate</td>
<td>11%</td>
<td>6%</td>
<td>8%</td>
<td>7%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Spell-Read Reaction Time</td>
<td>735</td>
<td>686</td>
<td>687</td>
<td>674</td>
<td>696</td>
<td>686</td>
</tr>
<tr>
<td>Error Rate</td>
<td>11%</td>
<td>5%</td>
<td>4%</td>
<td>6%</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td>Read-Spell Reaction Time</td>
<td>742</td>
<td>720</td>
<td>727</td>
<td>732</td>
<td>711</td>
<td>723</td>
</tr>
<tr>
<td>Error Rate</td>
<td>10%</td>
<td>5%</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Spell-Spell Reaction Time</td>
<td>742</td>
<td>699</td>
<td>700</td>
<td>708</td>
<td>709</td>
<td>704</td>
</tr>
<tr>
<td>Error Rate</td>
<td>10%</td>
<td>7%</td>
<td>9%</td>
<td>8%</td>
<td>6%</td>
<td>7%</td>
</tr>
</tbody>
</table>

Examination of the priming exhibited in each of the experimental conditions showed that significant priming was obtained in the READ-
READ condition, $t(23)=8.47$, $p=.0001$, the SPELL-READ condition, $t(23)=6.2$, $p=.0001$, and the SPELL-SPELL condition, $t(23)=4.21$, $p=.0003$. The READ-SPELL condition, however, did not produce significant priming, $t(23)=1.64$, $p=.1136$. The reaction time data in terms of priming scores were analyzed by a three-way analysis of variance (ANOVA) with prime type, target type and lag as factors. This analysis revealed a significant main effect of target, $F(1, 23)=12.54$, $MSe=10777$, $p=.0017$, with lexical decisions (i.e., read responses) being faster than spelling-probe decisions (i.e., spell responses). No significant main effect of prime type (read vs. spell) was obtained, $F(1,23)=1.10$, $MSe=4633.14$, $p=.3062$. No significant main effect of lag was observed for reaction time data, $F(3, 69)=0.24$, $MSe=3588.9$, $p=.8692$. Analysis of the interactions revealed a significant interaction of target type and prime type, $F(1,23)=14.53$, $MSe=4431.08$, $p=.0009$. All remaining interactions were not significant, all $p$'s $>.1$.

Figure 5 presents the patterns of priming exhibited in the various conditions across lags for reaction times.
In order to follow-up on the significant target type by prime type interaction, separate ANOVAs were carried out for each target type. For the read targets this analysis revealed a significant main effect of prime
type, $F(1,23)=19.24$, $MSE=2745.29$, $p=.0002$, and a marginally significant main effect of lag, $F(3,69)=2.24$, $MSE=2395.38$, $p=.09$. The interaction of prime type and lag was not significant, $F(3,69)=0.71$, $MSE=3094.02$, $p=.552$. The main effect of prime type was due to a larger priming effect in the READ-READ condition compared to the SPELL-READ condition (83 vs. 49 ms). Further examination of the marginal main effect of lag showed that LAG5 differed significantly from LAG1, $t(23)=-2.13$, $p=.044$, LAG2, $t(23)=-2.10$, $p=.0469$, and marginally differed from LAG10, $t(23)=2.01$, $p=.0562$. None of the other pairwise comparisons were significant. The same analysis for the spell targets revealed no significant main effects of prime type or lag, and no significant interaction of prime type and lag, all $p$'s $.1$. However, although not significantly different the pattern of effects (i.e., same task primes producing greater priming than different task primes) with priming in the SPELL-SPELL condition numerically greater than that in the READ-SPELL condition.

**Error Rate Analyses.** A three-way analysis of variance (ANOVA) of the error rate priming scores was carried out with prime type, target type, and lag as factors. This analysis revealed no significant main effects or interactions, all $p$'s $.1$. Because of the significant effect of lag on reaction times in the READ target condition, analysis of the error rates across lags in the READ target condition was carried out. This analysis showed no significant differences between the amount of priming obtained at any of the prime target lags, all $p$'s $.1$.

Figure 6 presents the patterns of priming exhibited in the various conditions across lags for errors.
Figure 6

Priming Percentage by Condition and Lag for Experiment 3:

Analysis by Items
A similar analysis, as those described above, was undertaken with items serving as the random factor instead of subjects. As items occurred
in a particular prime type, target type, lag configuration for only a single subject, it was necessary to collapse the data across lag in order to avoid contrasting single data points from different subjects at each level of the factors. Therefore, both the reaction time and the error rate data were analyzed by a two-way repeated measures ANOVA with prime type (read vs. spell) and target type (read vs. spell) as the factors.

Concordant with the overall analysis of reaction time data by subjects, analysis of the reaction time priming data by items revealed a significant main effect of target, $F(1,402)=15.87, \text{MS}_e=81813.68, p=.0001$, and a significant prime type by target type interaction, $F(1,402)=9.05, \text{MS}_e=29980.23, p=.0028$. The main effect of prime type for the reaction time priming data was not significant, $F(1,402)=0.08, \text{MS}_e=28523.45, p=.783$. Analysis of the error rate priming data by items revealed no significant main effects, all p's > .6. However, a significant interaction of prime type and target type was obtained, $F(1,427)=4.97, \text{MS}_e=.02, p=.0264$.

Discussion

The data obtained here provides conflicting evidence relating to the common or independent orthographic lexicon debate. The effects obtained from the reaction time data showed a significant difference between the effect of reading the prime and spelling the prime on later reading. This supports the contention that reading and spelling are not subserved by a common orthographic lexicon. However, there was no difference in the effect of read and spelled primes on the spelled targets. This supports the common lexicon view in that both reading a prime and spelling a prime helped later spelling to the same extent. These conflicting results might be
explainable within a "separate but linked" framework. This type of explanation is helped by the fact that, although not statistically significant, spelling primes produced greater priming than reading primes on spelling of targets. The differences between the patterns of priming effects exhibited for the different target types could also be explained by differences between the tasks (lexical decision and spelling-probe) themselves, and, most particularly, the spelling-probe task.

The spelling-probe task is relatively new, and little information is available as to the processes involved in this task. In general the spelling-probe task seems a bit more difficult to perform than a simple lexical decision task. In addition, in this particular experiment, lower frequency words were used in order to try and maximize possible priming effects obtained. All items used were below 20 occurrences per million according to the Kucera and Francis frequency norms (Kucera & Francis, 1982). In order to make it more likely that subjects adopted a lexical spelling strategy in completing the spelling-probe task, the items were chosen to contain irregular spelling-sound correspondences. This factor was not controlled systematically but an attempt was made to include as many irregular words as possible. These two factors (low frequency of the items and spelling irregularity of the items) may have served to make the spelling-probe task much more difficult. In this instance, therefore, subjects may have been forced into a greater reliance upon visual information when completing the spelling-probe task than the would have under less demanding situations. This forced reliance may have resulted in no difference between the influence of a read prime or a spelled prime on the spelling-probe task. Thus the appearance of effects suggestive of a common orthographic
lexicon in the spelling-probe task may actually be an effect of the difficult of the task itself and the items used. Further examination of these issues explicitly controlling for frequency and regularity would be necessary to fully explain the present data.

In addition to the effect of prime discussed above, a marginally significant main effect of lag was obtained for the read targets. Closer examination showed that the greatest amount of priming in these conditions was obtained at the five item lag. It is curious as to why this effect would occur at this lag. This effect suggests that the facilitation in repeating a particular item might reach its greatest level after five intervening items. However, further explanation of this finding would need to wait for subsequent replication of the present results.

General Discussion

The data presented from the first three experiments (Experiment 1, Experiment 2a, and Experiment 2b) argue most strongly against the common lexicon theory. No significant facilitation was found between reading and spelling in these experiments. In Experiment 1, only reading items at study resulted in significant amounts of priming on a perceptual identification task. In both Experiment 2a and 2b, only spelling items at study resulted in significant facilitation on later spelling. Although non-zero facilitation was exhibited from reading items at study, as discussed above, this effect was much less reliable than that exhibited for spelling.

The results of Experiment 3, however, do little to clarify this debate. Significant facilitation was observed for items presumably within a lexicon (read-read and spell-spell) and for items between lexicons (spell-read and read-spell). However, the data showed that there was a significant
influence of the type of prime on priming in the read conditions such that reading a word produced greater priming on subsequent lexical decision performance than did spelling that word. This difference, as stated above, suggests independent lexicons operating for reading and spelling. This difference for read targets is offset by no difference between the effectiveness of read over spelled primes on later spelling-probe performance. This lack of a difference for the spelled targets suggests a common lexicon shared by reading and spelling. The question remains as to how to explain these results in terms of the structure of the orthographic system involved in reading and spelling. It should also be considered that the fact that significant priming was obtained at all in the between task conditions (READ-SPELL and SPELL-READ) seems to be sufficient evidence to discount a completely independent lexicons view. This theory would predict no significant influence of read primes on a spelling task or spelled primes on a reading task. The presence of such effects would suggest that at the very least an independent lexicon view would need to be altered in such a way as to allow for the sharing of information between orthographic representations used for reading and those used for spelling. This form of an architecture would be what we have been considering as the "separate but linked" model.

It would seem necessary, then, to make a distinction based upon these data between the common lexicon view and the "separate but linked" view. Experiment 3 attempted to make this distinction by examining the influence of the number of intervening items on the pattern of priming effects obtained. It had been argued that any facilitation between different lexicons might exhibit a differential pattern of decay over time. That is,
between lexicon activation was expected to be less stable and decay faster than activation within a lexicon. This was assumed to be a function of the transference of information via possible connections between two separate input and output orthographic lexicons. This interaction was the critical one for distinguishing a "separate but linked" architecture from a common lexicon architecture. The data from Experiment 3, however, revealed no significant interaction with lag for the spelled target trials. The effect of lag across the read trials was only marginally significant. These data, therefore, do little to clearly distinguish between a common lexicon theory and a "separate but linked" theory. It is possible that differences across time would be more apparent with longer lags between repetitions than utilized here. Further support for a "separate but linked" theory might be obtained if it is possible to discount some of the data presented in support of a common lexicon view.

There is much evidence from the neuropsychological literature suggesting independent lexicons. Some neuropsychological evidence has been presented which appears to strongly support a common lexicon theory. However, what little evidence exists in the normal literature related to this issue presents mixed results. Previous studies may suggest that there is some reason to opt for a "separate but linked" theory over either of the other two theories. Since the data from Experiment 3 seem to argue against a completely independent lexicon theory and in reality the "separate but linked" theory can be seen as a modified version of the independent lexicons theory the focus of the remaining discussion will be upon distinguishing this "separate but linked" architecture from one that includes a single common orthographic lexicon for reading and spelling.
Evidence from Non-brain-damaged Subjects

The data reported by Monsell (1987b) seem to be the most easily reconciled with the current results. Monsell reported finding evidence for facilitation from spelling a word without viewing the output to later visual recognition of that word. This facilitation, however, only occurred when a sentence stimulus remained present on the computer screen as the subject produced an item. (In a different task, Monsell and Banich (unpublished, see Monsell, 1987b) had failed to find any facilitation from spelling to reading.) It was Monsell's contention that under circumstances whereby the subjects' processing capacity was "stressed", they utilized a "sublexical output-input loop" to provide extra capacity. Thus, output representations made contact with orthographic input representations in a "separate but linked" lexicon. Though the current results might lead us to adopt a "separate but linked" lexicon explanation, the idea that this linkage would only be exploited under processing capacity limitations seems a bit farfetched given that the study task utilized by Monsell (1987b) hardly seemed to seriously stress a normal subjects capacity (Capacity was assumed to be "stressed" by the continued presentation of the sentence stimulus. Presumably, subjects were unable to stop this stimulus from utilizing capacity they could have used for producing the word even though once read the sentence was irrelevant to the subsequent task.) Any attempt to evaluate such a processing limit explanation would have to examine these issues under circumstances which varied demands on cognitive capacity in a more direct fashion than in Monsell's experiment. If the somewhat mixed results of the present experiments can be taken as weak support for a
linkage between an input orthographic lexicon and an output orthographic lexicon, then any connection would appear to operate on an automatic basis, contrary to Monsell's explanation.

The Jacoby and Hollingshead study (1990) would appear to be slightly more problematic. As discussed above, two possible explanations are put forth by Jacoby and Hollingshead. One is that both the misspelled representation and the correct spelling are represented in a common orthographic lexicon. Thus, visual presentation of a commonly misspelled word accesses this representation and results in a greater probability of that misspelling being produced. It was also proposed that the facilitation could result from the automatic, unconscious construction of a lexical representation for the misspelled word. As recognition memory performance was not predictive of spelling performance (indicating recognition of an item as a previously studied item did not influence spelling accuracy) this seems an unlikely explanation. However, these data could also be accounted for by a "separate but linked" lexicon theory. It is possible that subjects could have lexical representations for commonly misspelled words in both an orthographic input and an orthographic output lexicon. These representations share information and thus when a commonly misspelled word is read (in its misspelled form), it also activates its misspelled form in the output lexicon making it more likely that the misspelling will be produced. Although it might be argued that this is an exceedingly complex explanation, it seems the most likely given that the current data argue against a common lexicon theory.

The data discussed previously in regards to non-brain-damaged subjects appear to fit quite easily within a "separate but linked" lexicon
theory. Neither the results of Monsell (1987b) nor those of Jacoby and Hollingshead (1990) would appear to fit easily within an independent lexicon theory. In addition to the normal studies discussed here, it is necessary to determine if the neuropsychological data can be accounted for as well, most importantly for the present discussion, is whether the patient data can be adequately accounted for without resorting to a common lexicon theory.

**Cognitive Neuropsychological Evidence**

For the most part the neuropsychological evidence discussed earlier can be quite handily explained by a theory other than a common lexicon theory. In fact, relatively few of the studies accounted for their data in this manner (see Coltheart & Funnell, 1987; and Behrmann & Bub, 1992 for exceptions). Data from letter-by-letter readers (Kay & Patterson, 1982; Warrington & Shallice, 1980), pure agraph patients (Beauvois & Derousne, 1981; Shallice, 1988), and deep dysgraphic patients (Bub & Kertesz, 1982b) can be accommodated by either an independent or a "separate but linked" lexicon theory. Both theories have separate lexical orthographic representations for input and output so either input or output representations could be damaged while sparing the other. Unless one makes the assumption that connections between input and output orthographic representations in some way help facilitate processing on a given level it does not seem likely that damaging a connected lexical representation on the input side (or the connection between that input representation and its corresponding output representation) would necessarily impair functioning on the output side and vice versa. Therefore, patterns of impairment predicted by damage to one component
or another should be the same for either and independent lexicon theory or a "separate but linked" theory.

Campbell (1987) presented the cases of two developmental dysgraphics who exhibited poor spelling judgment performance for words they consistently misspelled words along with good spelling judgment for words they consistently correctly spelled items. In addition, however, they also performed well at judging correct spellings of the words they consistently misspelled words, as well as correct control spellings, and control misspellings (i.e., they correctly rejected these control misspellings better than they did their own consistent misspellings). Campbell (1987) interpreted her findings in terms of an independent lexicon theory. This explanation does not seem to be necessarily inconsistent with the results of the current experiments. However, given the data from Monsell (1987b), and Jacoby and Hollingshead (1990), it would appear that reinterpretation in terms of a "separate but linked" theory may be necessary. One might assume that these patients have a consistent misspelling represented in an output orthographic lexicon but intact input orthographic lexicon representations. This would account for the consistent misspelling as well as good spelling judgment performance on consistently correctly spelled words. If the input and the output lexicon are linked, it is possible that when these individuals attempt to make a spelling judgment any activation or sharing of information which comes from the output lexicon interacts with the input processes involved in spelling. Thus, for the consistently misspelled items, incorrect information is being fed up from the output lexicon to the input lexicon and interfering. Therefore for consistently
misspelled words the information available for spelling judgment may be more noisy and more error prone then for other types of items.

Of all the neuropsychological data discussed it is most critical to account for the patients studied by Coltheart and Funnell (1987) and Behrmann and Bub (1992). Both these case studies were interpreted as strong evidence for a common lexicon theory. Given that the results of the current experiments contradict such an interpretation, it is necessary to explain these patients in some way without reference to a common orthographic lexicon for reading and spelling.

Typically, most models of reading assume two processes. One is a lexical route mediated through a semantic system and the other is a sublexical route involving the translation of graphemes to phonemes via some sort of conversion process. Some researchers also include a third route in these models which involves the direct mapping of input lexical orthographic codes to output lexical phonological codes. The inclusion of this third direct lexical route is still a hotly debated issue in the field and therefore most theories assume only the standard two-route model. As mentioned the lexical route involved in the two-route model is a semantically mediated one. Studies related to the functioning of a lexical route in input and output must pay close attention to the role the semantic system plays in these processes. It is possible to observe consistency between reading and spelling performance due to a deficit at this shared semantic level. As stated, the semantic component is common to both input and output lexical orthographic processing. Lexical reading and writing most assuredly draw upon the semantic component. A problem of any kind at the level of the semantic system would be sufficient to cause a similar
deficit in both reading and writing. Any correspondence then would be
due to this shared semantic component and not to any sharing of
information at the level of the orthographic lexicon. It is, therefore,
necessary to account for any effects at the semantic level when examining
the correspondence in reading and spelling performance. Though they did
take the into account effect of frequency, Coltheart and Funnell (1987)
failed to consider semantic level factors such as imageability in their
assessment of the consistency of their patient's reading and spelling
performance. A semantic level locus of the correspondence between
reading and spelling errors in their patient cannot be discounted.

Much more difficult to accommodate within a "separate but linked"
or independent lexicon theory is the patient described by Behrmann and
Bub (1992). This surface dyslexic and surface dysgraphic patient exhibited
similar reading and spelling performance. She seemed to have a lexical
level difficulty in reading and spelling words (particularly low frequency
irregular words) along with a well-preserved sublexical reading ability.
Most importantly, this patient exhibited a significant item-by-item
correspondence (Behrmann & Bub report an overall sample Kappa of 0.62
(0.86, 0.51, and 0.50 respectively for three frequency bandwidths (10-19
per million, 20-49 per million, and 50-99 per million)) between reading
and spelling even when frequency, word length, and imageability were
taken into account. Behrmann and Bub explained this correspondence in
terms of a common orthographic lexicon for reading and spelling. Table 5
presents the consistency data from Behrmann & Bub (1992) for items
correctly and incorrectly spelled and correctly and incorrectly read across
the three frequency bandwidths.
Table 5
Consistency of Accuracy between Reading and Spelling for Patient MP
(Behrmann & Bub, 1992) across Frequency:

<table>
<thead>
<tr>
<th></th>
<th>Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-19</td>
</tr>
<tr>
<td></td>
<td>Correct</td>
</tr>
<tr>
<td>Writing</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Incorr.</td>
</tr>
<tr>
<td></td>
<td>0</td>
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</tbody>
</table>

This case, MP, presented by Behrmann and Bub (1992) would appear to present strong evidence for the common lexicon view. It is clear that MP exhibited an impairment to input lexical orthographic representations (particularly for low frequency words as evidenced by her lack of an advantage for words over nonwords in a visual recognition task). MP, however, had a severe semantic deficit. Her performance on an auditorily presented version of the Peabody Picture Vocabulary Test (PPVT) placed her at a vocabulary age equivalent of 2.8 years. This test involves the presentation of a set of four pictures and an auditory word. The subjects task is to point out the picture which best matches the meaning of that word. MP's raw score on this test was 31. The items represented at this level are very concrete and imageable items. The requirements of the model which Behrmann & Bub adopted to explain their patient's data require that any lexical reading be mediated through the semantic system. MP has a semantic deficit for both concrete and abstract items (as evidenced by her poor performance on the PPVT). Yet, surprisingly,
Behrmann & Bub (1992) use imageability as the factor to account for any influence of the semantic system on the correspondence between MP's reading and spelling performance. It is obvious that MP's semantic deficit is in no way related to the level of imageability associated with a particular item. This would suggest that there is some other, as yet undetermined factor, which is causing MP's semantic impairment. Until it is determined what that factor may be, there is no way to rule out MP's semantic level deficit as the explanation for the correspondence between her reading and spelling impairments.

**Why a "Separate but Linked" System?**

The data presented from the current experiments as well as the data from others (notably Monsell, 1987b) seems to point to a system of separate orthographic lexicons (one for input processing and one for output processing) that have connections between them and thus share information. The question remains as to what the role of these connections might be. Surely they do not exist solely for the purpose of exhibiting repetition priming. Therefore, we should consider the possible role (or roles) they might play in the normal functioning and development of the reading and spelling systems.

Anecdotally one can think of many situations when presented with a difficult or commonly misspelled word (like for example, "committee") one has written that word down and looked at it to try and determine visually whether the word is spelled correctly. In this example consider a "separate but linked" orthographic lexicon. The connections between input orthographic representations and output orthographic representations might serve a sort of monitoring function or spell checker during spelling.
As items are spelled, what is written might be "spell checked" against input orthographic representations used in reading. As an item is written, the spell checker kicks in to guide the production. A spell checking system of this type might be most likely to come into play with irregularly spelled words (along with those difficult to spell, or low frequency items). Spelling of regular words, presumably, could be checked by this lexically based spell checking system or by retranslation of the written output via sublexical means.

Another function of these connections between input orthographic representations and output representations could be their use in the learning process. Individuals learn to read prior to learning to spell. Connections might develop as the newly forming system starts to relate individual graphemes to individual phonemes. As the system grows it becomes more important to create whole word representations for spelling rather than producing a word's spelling sublexically (the whole word lexical method would be more efficient). In order to lay down these whole word lexical orthographic representations for output, the system utilizes more stable information in the orthographic input lexicon. It basically uses the input representations to create the output ones. This process is accomplished over time via the connections between the two lexicons. They may continue to serve throughout our lives in helping to lay down new output orthographic representations for new words.

Conclusion

The debate on the status of orthographic lexicons within the language processing system continues. It is still unclear if the data can differentiate between a common and a "separate but linked" architecture. Previous
studies, both with brain-damaged and non-brain-damaged subjects, which claim to provide support for a reading and spelling system which share a common orthographic lexicon appear to have some problems in discounting alternative explanations. The data presented here in Experiment 3 seems to discount an independent lexicons theory. The compromise position would most clearly seem to be a "separate but linked" theory. As discussed above, this theory would account for some of the data presented here as well as for much more of the neuropsychological data used to support both a common and an independent lexicon theory. Additionally, arguments can be made as to the possible functioning of such an architecture. Therefore, a "separate but linked" theory appears to be able to account for the data from both non-brain-damaged and brain-damaged subjects in a reasonable and parsimonious manner.
References


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